too change to suit the evolving style of architecture which itself fades away in ten or twenty years. But the rebuilding is scarcely possible without the preexisting structure as the old is the very means for us to come upon the new. We are nothing without our predecessors, yet we are more.

Beneath the magic mansion, however, is a permanent foundation which age does not wither nor change consume. The foundation draws its permanence from compassion to fellow-humans and the search for wisdom which lend substance and meaning to all human endeavour. So long as the foundation lasts, it will support the edifice for all seasons, however mighty and moveable it may be. Charaka said that the practice of medicine is neither for self-aggrandisement nor for pleasure, but for the sake of compassion to fellow humans. Twenty centuries later, cardiac surgery can say that again.

**S&T IN INDIA**

# DHRUVA—The versatile nuclear research reactor at Trombay

*S. K. Sharma*

Nuclear research reactors form the base of any well-defined nuclear programme in a country. With experience of over 30 years in the operation and utilization of research reactors such as Apsara, Cirus, Zerlina and Purnima, the need for a high flux modern research reactor which can provide better facilities for research, isotope production and engineering experiments was felt. DHRUVA, a 100 MWt research reactor with a thermal neutral flux of $1.8 \times 10^{14}$ neutrons $cm^{-2} sec^{-1}$ was therefore set up at the Bhabha Atomic Research Centre (BARC), Trombay, during 1985. The concept, design, detailed engineering, construction, commissioning and operation have been entirely through indigenous efforts. Besides engineers and scientists of BARC, many governmental institutions and public and private sector industries took part in this project. Dhruva attained first criticality on 8 August 1985 and its rated power operation was achieved in January 1988.

## General description

Dhruva is a vertical tank type reactor with a maximum power level of 100 MWt (megawatt thermal). The reactor is fuelled with natural uranium and is cooled, moderated and reflected by heavy water. The reactor core is located inside a vertical stainless steel reactor vessel, also known as calandria, placed inside a light water-filled concrete vault. Inside the reactor vessel, 146 vertical guide tubes are placed. Two of these guide tubes are used for installation of engineering loops and three for conducting corrosion and irradiation-induced creep measurements. The remaining positions are used for housing fuel assemblies, radioisotope production as-

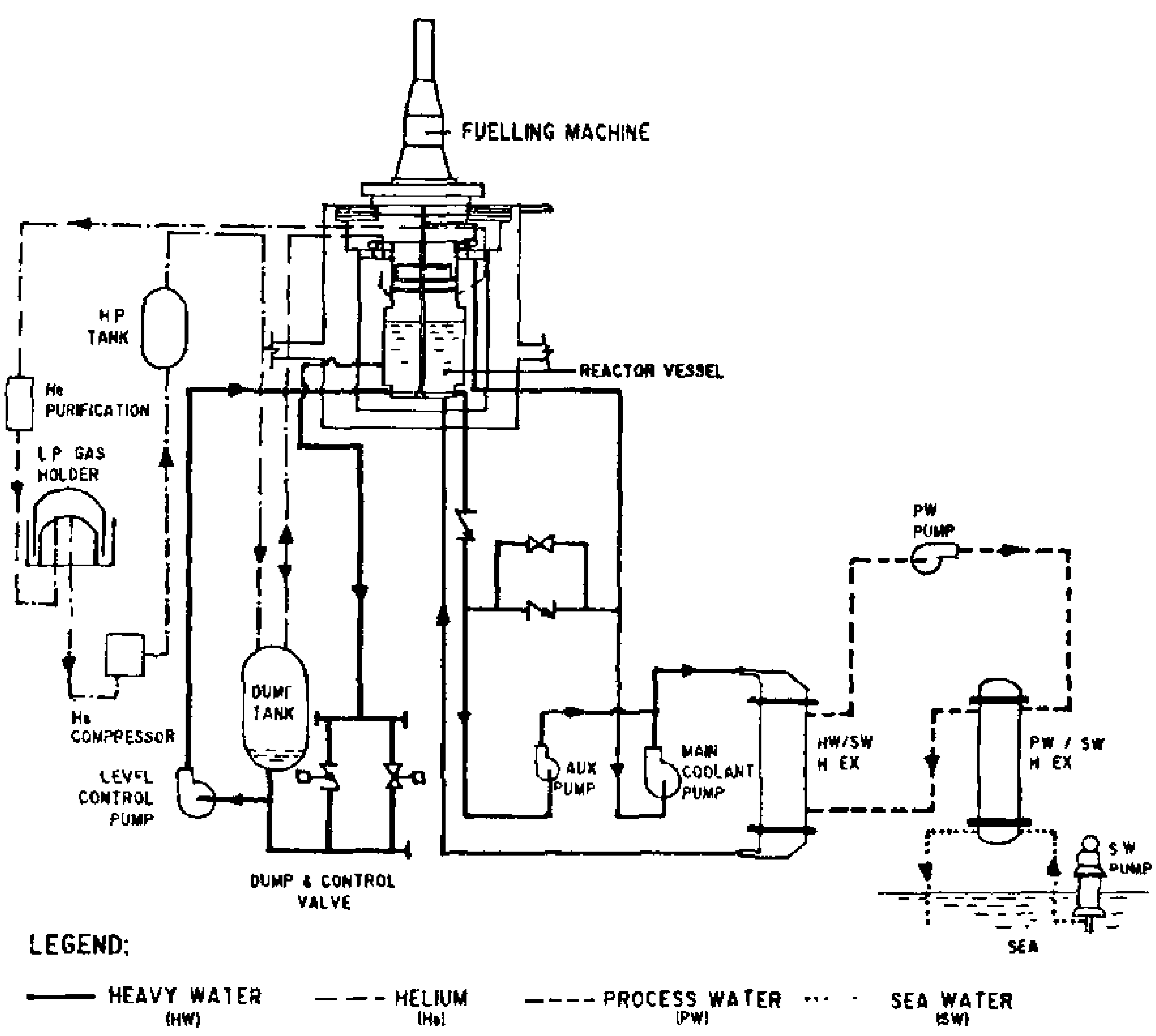


Figure 1. Simplified process flow diagram

semblies and shut-off rods. The guide tubes support the fuel assemblies and provide a flow-path for the coolant heavy water.

The coolant is pumped into an inlet plenum at the bottom of the calandria from where it flows upwards through fuel assemblies and exits through tail pipes at the top of individual coolant channels. All the tail pipes join into a common outlet header from where the coolant flows to the suction of main coolant pumps and is pumped through heat exchangers back to the reactor inlet plenum. Coolant recirculation is maintained through three independent loops and the pumps, heat exchangers and other associated equipment for each loop are housed inside separate concrete shielded cubicles located inside the basement and sub-basement of the reactor building. Heavy water is cooled in the heat exchangers by light water, which is also maintained in a closed loop recirculation. The light water coolant is cooled in another set of heat exchangers by sea water which flows in a once-through mode.

Heavy water in the calandria (outside the guide tubes) acts as moderator to control the reactor power and is recirculated by means of pumps. Its outflow from the reactor vessel is controlled by control valves. The reactor power is sensed by neutron flux monitoring instruments located around the reactor vessel and compared with the desired operating power level set from the main control room. The difference between these signals, called 'error-signal', is fed to electropneumatic positioners to control the openings of the valves and obtain the desired moderator level in calandria.

Helium, used as cover gas over the heavy water moderator, flows through the calandria to a purification system where entrained moisture is removed in cyclonic separators, coolers and freeze-driers. Radiolytic decomposition products of heavy water are recombined by passing the cover gas through palladium recombiners. To remove fission gases and impurities such as nitrogen and carbon dioxide, the cover gas is passed through liquid nitrogen-cooled activated charcoal adsorber beds. Helium is then pumped back to the calandria using diaphragm compressors.

### Safety features

Dhruva has been provided with engineered safety systems to bring the reactor to a safe shut-down state in the event of abnormal operating conditions. Provisions also exist for cooling the irradiated fuel under all postulated conditions and for preventing radioactivity leakage in the unlikely event of an accident.

#### *Reactor shut down mechanisms*

If any of the operating process parameters go beyond their pre-set limits, the reactor automatically shuts off by insertion of 9 cadmium shut-off rods into the reactor core. During normal operation, these rods are held above the reactor core by electromagnetic clutches. The moderator level in the reactor vessel is also brought down to a pre-determined value by tripping the moderator recirculating pumps and opening the dump and control valves at the bottom of the reactor vessel. Moderator dumping acts as a back-up shut down system for long-term shut down safety. In case of inadequate or slow actuation of shut-off rods or moderator dump, liquid neutron poison is injected into 20 tubes located in the interlattice positions of calandria.

#### *Shut down cooling*

When the main coolant recirculation pumps stop, the reactor is shut down automatically. However, the reactor fuel needs to be cooled even under reactor shut down condition for removal of decay heat. Therefore, small capacity pumps are provided in parallel with the main pumps. When the main pumps trip, the small pumps start automatically providing shut down cooling to the fuel.

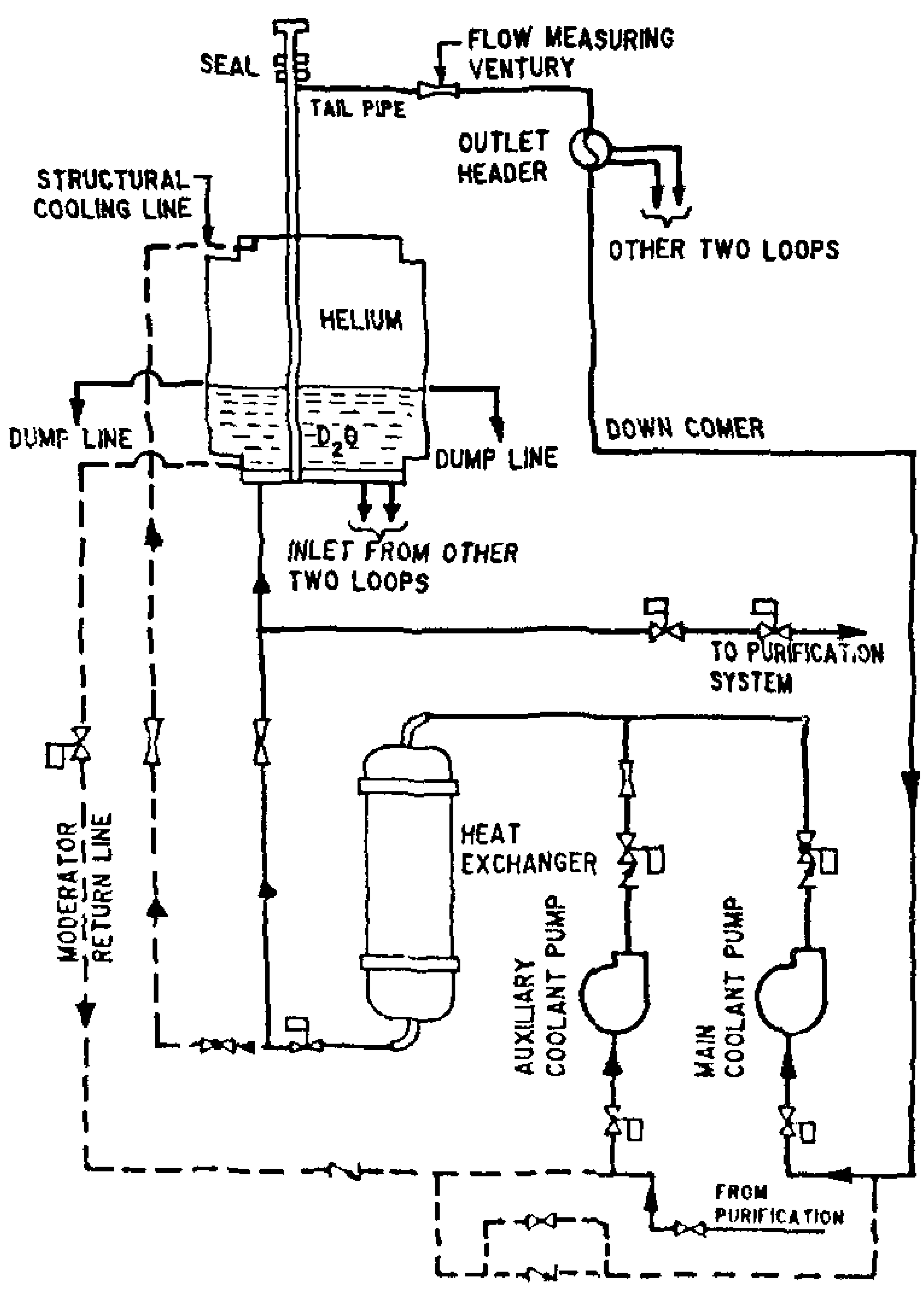


Figure 2. Main coolant flow diagram.

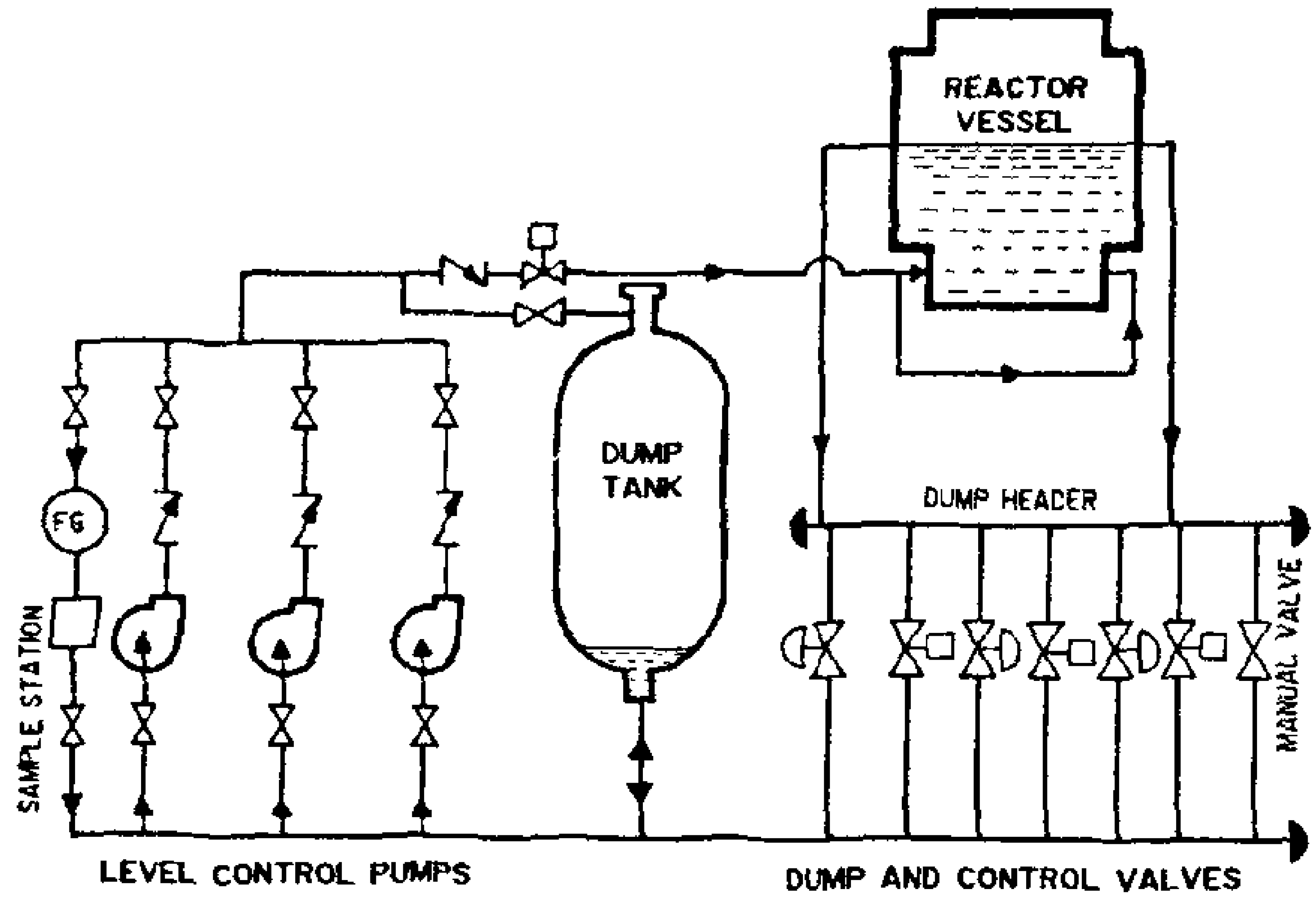


Figure 3. Moderator level control system.

Heavy flywheels are mounted on the main coolant pump shafts such that coolant flow through the reactor core coasts down slowly ensuring adequate coolant flow till the smaller pumps start and establish shut down cooling flow. The smaller pumps are provided with two prime movers mounted on the same shaft. One of them is an electrical motor provided with uninterrupted power supply and the other is a water turbine driven by gravity flow of water from an overhead reservoir to an underground tank. Emergency diesel generators and battery banks provide uninterrupted power supply to the motor prime-movers and for pumping water from the underground tank to the overhead reservoir. They also supply power to other essential equipment in the plant.

*Emergency core cooling*

An emergency core cooling system cools the fuel assemblies even under the most unlikely situation of failure of primary coolant piping. The coolant heavy water which escapes from the failure locations in the primary coolant piping is collected in a tank through a network of drain piping. Heavy water from this tank is then pumped back into the reactor core for cooling the irradiated fuel. Instrumentation is provided for sensing abnormal coolant loss from the system and automatic injection of leaked-out heavy water into the reactor core. Provision also exists for injecting light water from an overhead tank as a back-up.

*Containment*

The entire reactor block and all the equipment connected with the reactor coolant, moderator and cover gas systems are located inside a concrete containment building which is equipped to ensure that no radioactivity escapes into environment in the most unlikely event of an accident. Once-through ventilation is provided for the containment building. During abnormal conditions, the normal ventilation is automatically stopped and the containment building completely isolated. An emergency exhaust system with activated charcoal filters and high-efficiency particulate air filters for removal of radioactive iodine and particulate activity is provided for operation under emergency conditions, if required.

## Research facilities

Several research facilities have been provided in Dhruva for engineering experiments, neutron activation analysis, condensed matter research and fission physics investigations. For engineering experiments, 2 pressurized water loops of 2 MW and 150 kW capacity have been provided. In these loops, coolant is recirculated at high pressure and high temperature, simulating the operating conditions of nuclear power plants. These loops are utilized for irradiation testing of power reactor fuels. In addition to pressurized water loops, experiments to study corrosion behaviour and irradiation-induced creep of materials used in nuclear power plants are also possible.

For neutron activation analysis, a pneumatic carrier facility has been provided which transports the samples

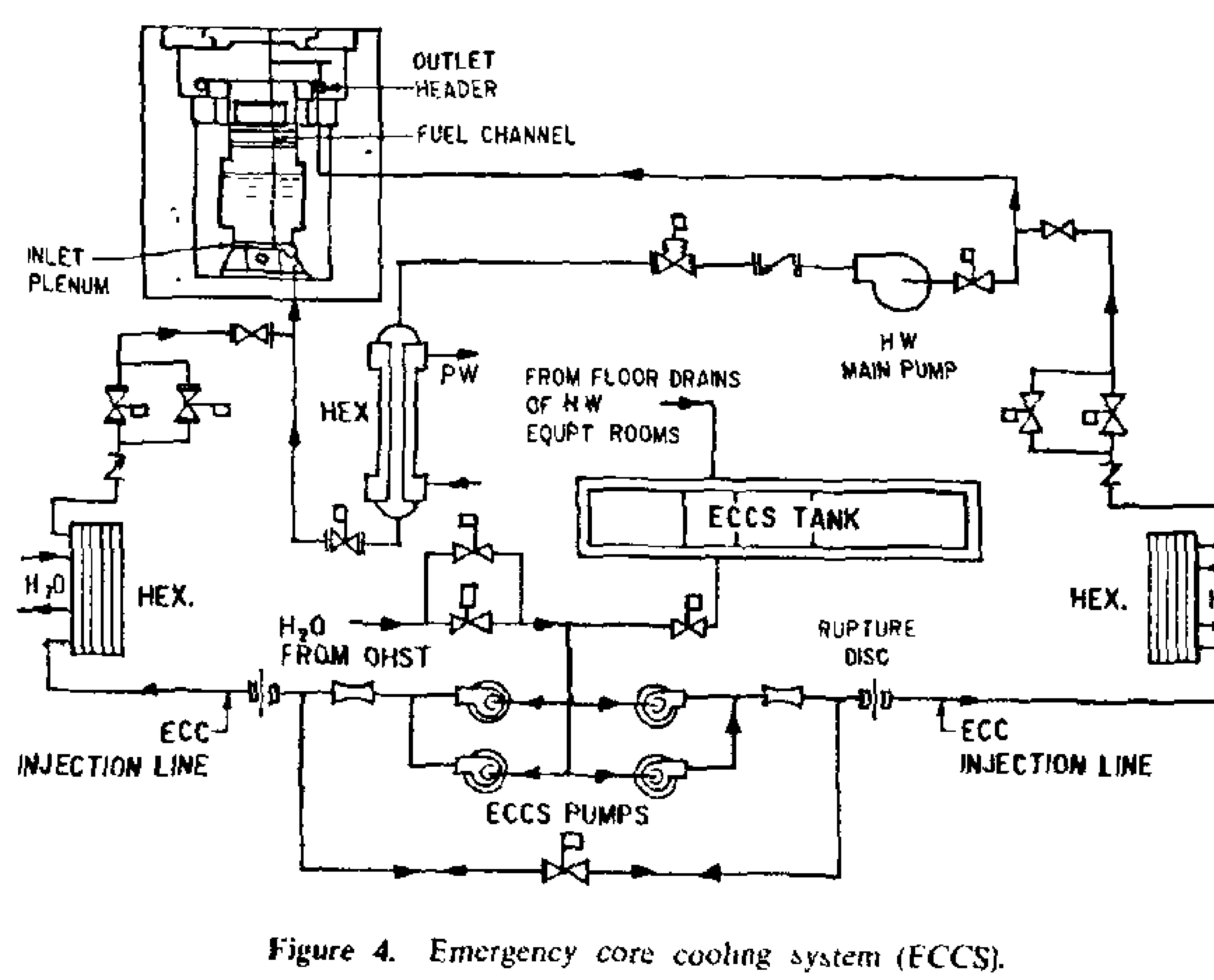


*Figure 4. Emergency core cooling system (ECCS).*

from a laboratory located outside the reactor building to an assembly inside the reactor core. After irradiation, the samples are retransported to the laboratory pneumatically. The entire cycle of shooting-in and shooting-out of the samples as also the control of irradiation and transit time are fully automated. Neutron activation analysis is used for several applications in material sciences, earth sciences, environmental and life sciences, forensic sciences and archaeology.

A large number of horizontal beam hole facilities have been provided in Dhruva for neutron beam experiments. The beam holes extend from the calandria to the outer face of the concrete biological shield around the reactor. Radial and tangential beam holes as also through-tubes extending across the biological shield and traversing through the calandria have been provided. In addition, there are special beam holes provided for cold neutron and hot neutron sources. Cold neutrons are transported using neutron guides to a laboratory located adjacent to the reactor building for conducting experiments in low gamma and neutron background conditions. The neutron beams obtained through beam holes are used in a variety of ways using sophisticated on-line computer-controlled instruments, to study the engineering, metallurgical, chemical, biological and other properties of nuclear materials such as characteristics pertaining to crystallinity, magnetic structures, nature of atomic motion, etc. The neutron beams are also utilized for a variety of fission physics experiments.

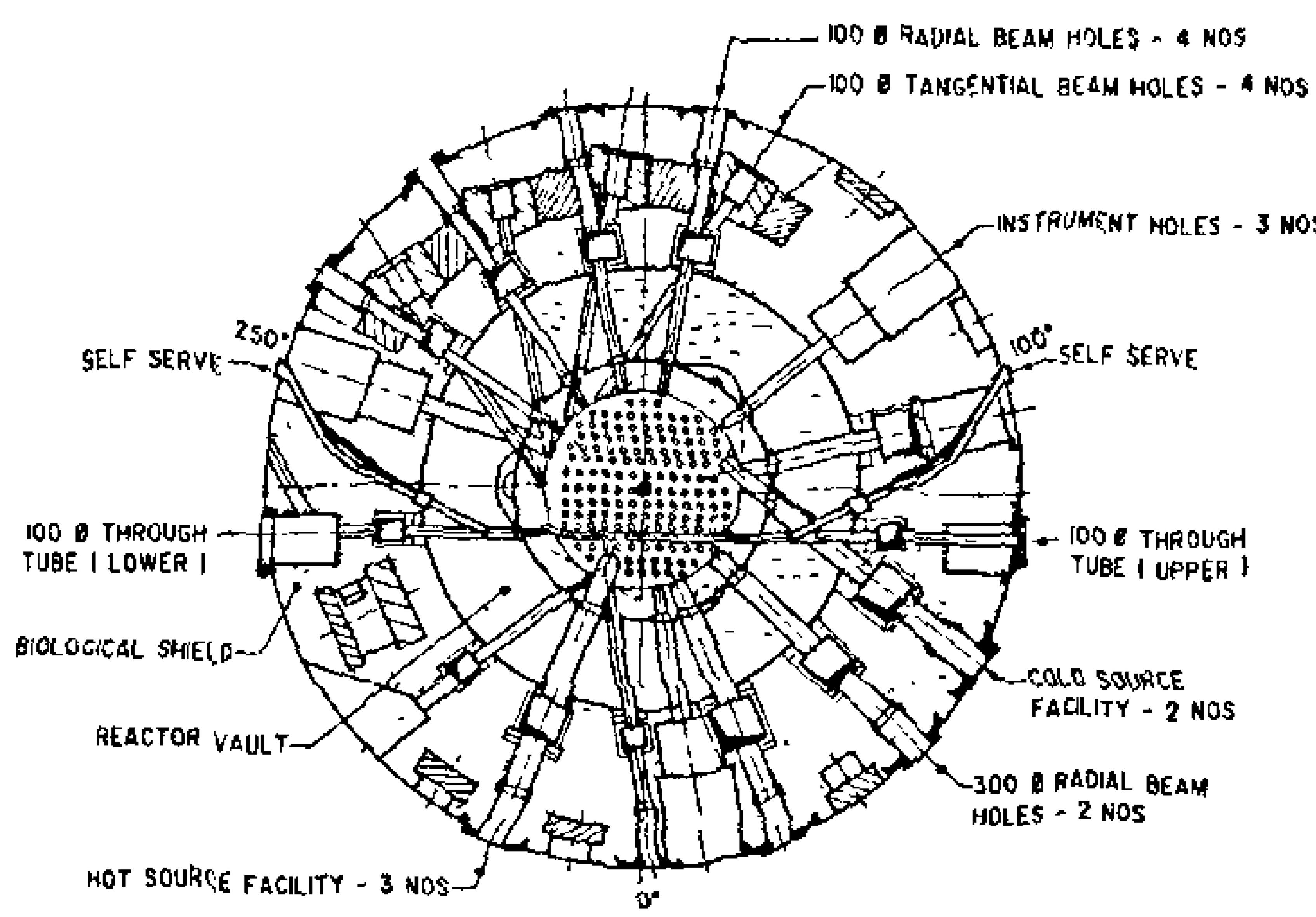


**Figure 5.** Horizontal beam holes in Dhruva.

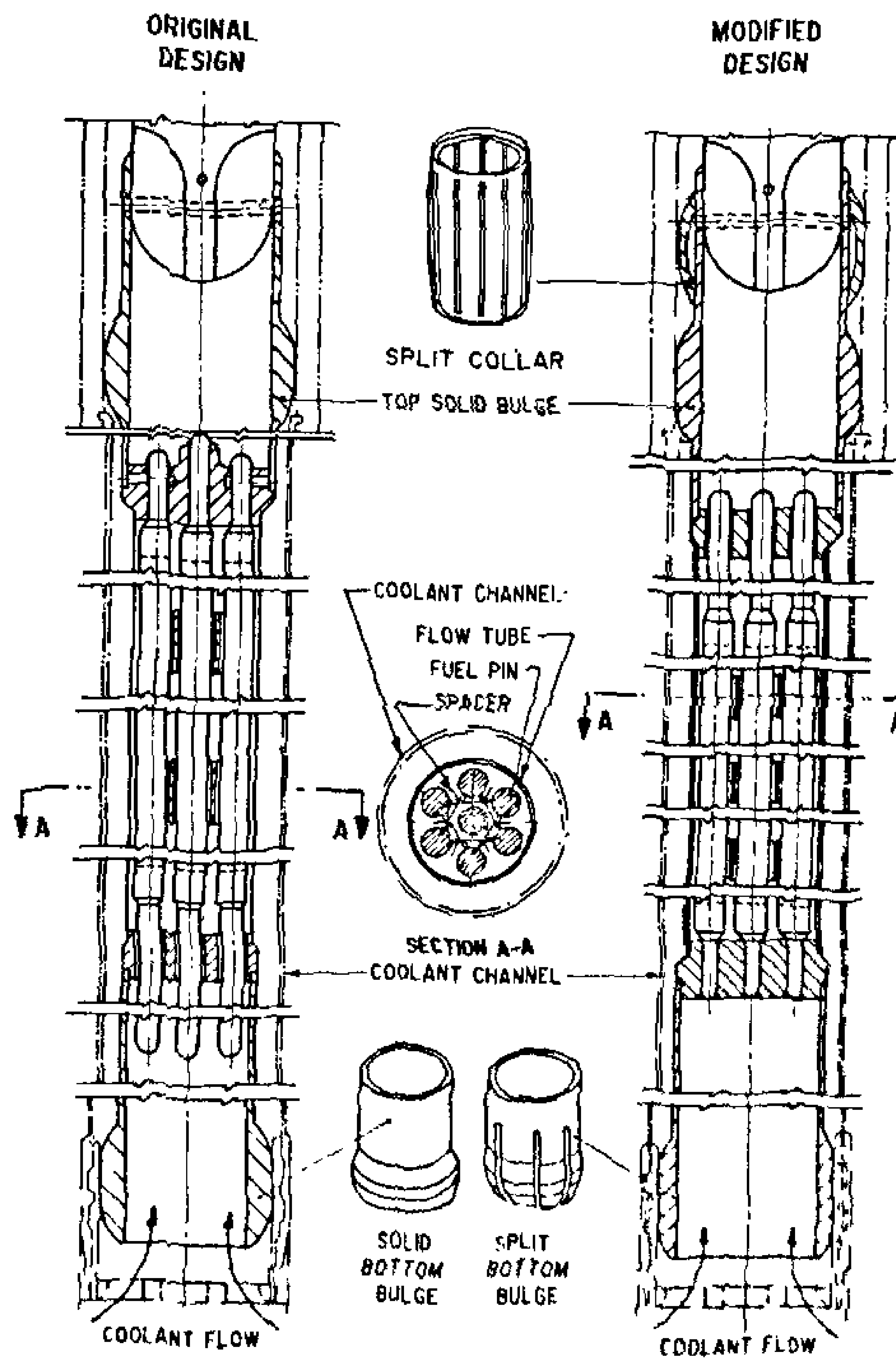


**Figure 6.** Dhruva fuel.

## Isotope production

For production of radioisotopes, tray rods are installed inside the reactor lattice positions. Samples of target material are enclosed in small aluminium containers which are placed in the tray rods for irradiation. On completion of irradiation, the tray rods are transferred to a shielded cell where these samples are removed remotely by master-slave manipulators. The samples are then loaded into shielded containers and transported to radioisotope laboratories for further processing. The tray rods can be installed and removed with the reactor in operation. In addition, self-serve facilities are provided for producing smaller quantities of isotopes at relatively lower neutron flux levels. In these facilities the aluminium container containing the target material is placed inside a hollow spherical aluminium ball and the ball is rolled into the irradiation location under gravity. At the end of irradiation, the ball is rolled out into a lead-shielded container and then further processed in the radioisotope laboratories. For production of cobalt-60, cobalt-slug rods are used for long-term irradiation in the reactor. These are removed from the reactor after about 4 years of irradiation such that cobalt-60 with a specific activity of about 50 Ci $g^{-1}$ is obtained. Radioisotopes find extensive applications in a variety of areas in medicine, industry and agriculture.

### Commissioning experience

During the initial phase of power operation, radioactivity levels in the coolant heavy water were much higher than expected. This was caused by the failure of aluminium cladding on uranium fuel rods due to severe mechanical wear which was in turn due to excessive flow-induced vibration of fuel assemblies. The design of fuel assemblies was therefore modified by incorporating split-bulges at the top and bottom of uranium fuel sections for eliminating the small clearance between the fuel assembly and coolant channel.

Due to the abrasion of aluminium cladding, turbidity in colloidal form appeared in the heavy water coolant. A special magnesium loaded ion-exchange resin matrix was therefore developed and used for turbidity removal. A centrifuge separation technique was also used for removing turbidity from the system heavy water.

With the modified fuel assemblies installed in the reactor, operation was resumed during November 1986 and the rated power operation achieved during January 1988.

Dhruva, one of the most powerful research reactors in the world today, has provided a great impetus for work in frontier areas of scientific and engineering research and radioisotope production. It has been declared as a national facility and the neutron beam facilities are open to all users in India.

*S. K. Sharma is Associate Director, Reactor Group, Bhabha Atomic Research Centre, Trombay, Bombay 400 085.*

REVIEW ARTICLE

# Protein-tyrosine phosphatases as regulators of protein kinase activity

**Ghanshyam Swarup and V. Radha**

Centre for Cellular and Molecular Biology, Uppal Road, Hyderabad 500 007, India

**The enzyme activity of many tyrosine-protein kinases and some serine/threonine protein kinases, which are critically involved in signal transduction pathways, is dependent on the level of phosphorylation at one or more tyrosines. Dephosphorylation of these phosphorylated tyrosines by protein-tyrosine phosphatases (PTPases) can activate or inactivate these enzymes. Activation occurs when PTPase acts on the negative regulatory site whereas inactivation of the enzyme occurs when PTPase acts on positive regulatory site. Both positive and negative regulatory sites are present on some protein kinases; these, therefore, may require two distinct PTPases for the regulation of their activity, although other mechanisms of regulation may also exist.**

PHOSPHORYLATION is one of the most widespread mechanisms adopted by the cell in controlling timely activities of various proteins. Such a post-translational modification is dependent on 2 classes of enzymes—the protein kinases and the phosphoprotein phosphatases. In recent years, we have gained insight into the significant role of tyrosine phosphorylation events in cell division, differentiation, transformation and development[1,2]. The phosphorylation state of any substrate at a given time depends on the action of the protein kinases and phosphoprotein phosphatases, necessitating critical regulation of the activity of these enzymes. Evidence is now available to suggest that the activity of some of the Ser/Thr protein kinases and many tyrosine-protein kinases is regulated by the phosphorylation state of their tyrosine residues. The interaction between kinases and phosphatases may, therefore, in certain cases, be more direct. Activity of kinases may be determined by their being substrates for PTPases.

## Structure of PTPases: Catalytic domains of all PTPases are conserved

PTPases constitute a novel class of enzymes and do not show sequence homology with other phosphatases such as Ser/Thr phosphatases[3]. They are present ubiquitously in a wide variety of tissues[4,5]. The first PTPase to be purified and sequenced was a 35 kD soluble enzyme from placenta[3]. It was found to be homologous to CD45, a transmembrane receptor-like protein present on the surface of lymphocytes. CD45 was then tested and found to possess PTPase activity[6]. The presently